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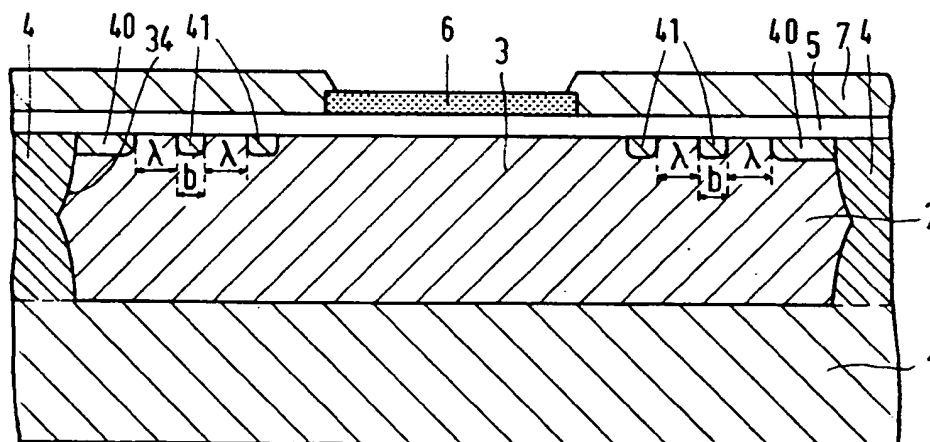
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(54) Semiconductor device with means for increasing the breakdown voltage of a pn-junction.

(57) A semiconductor device comprising a semiconductor body (1, 2) with an island-shaped region (3) adjoining the surface, in which a contact pad (6) is provided above the island-shaped region (3) and separated therefrom by an insulating layer (5). The

island-shaped region (3) forms a pn-junction (34) with an adjoining insulating region (4). According to the invention, the device is provided with means (40,41) for increasing the breakdown voltage of the pn-junction (34).

**FIG.2****EP 0 521 558 A2**

The invention relates to a semiconductor device comprising a semiconductor body with an island-shaped region of a first conductivity type adjoining the surface and surrounded by an insulating region of a second, opposite conductivity type with which the island-shaped region forms a pn-junction, the island-shaped region being covered by an insulating layer on which a contact pad is provided.

Such a device is known from US Patent 3,812,521. This describes a device in which the contact pad is separated from a p-type island-shaped region by a silicon oxide layer. The p-type island-shaped region lies in an island-shaped n-type insulating region with which it forms a pn-junction. In the known device, the n-type insulating region is in its turn surrounded by a p-type insulating region which is in electrical contact with the substrate.

It was found in practice that a device of the kind described frequently gives rise to failures in applications for higher voltages. The known device, therefore, has the disadvantage that it cannot be reliably utilized for higher voltages.

The invention has for its object *inter alia* to counteract this disadvantage by providing a device of the kind described in the opening paragraph which can be reliably used also at higher voltages.

According to the invention, a device of the kind described in the opening paragraph is for this purpose characterized in that the device is provided with means for increasing the breakdown voltage of the pn-junction between the island-shaped region and the adjoining semiconductor region.

The invention is based on the recognition that, when a short-circuit arises between the contact pad and the island-shaped region, the voltage at the contact pad is applied fully across the pn-junction between the island-shaped region of the insulating region, so that the pn-junction must be able to withstand the voltage offered at the contact pad.

Such a short-circuit may be due, for example, to fastening of a metal wire to the contact pad. Pressure is usually exerted on the contact pad during this, so that stresses are introduced into the subjacent insulating layer, and small cracks may arise. A short-circuit between the contact pad and the island-shaped region is possible through such a crack. This problem arises especially when the insulating layer between the contact pad and the island-shaped region is comparatively resilient, for example, in that the layer was not grown but deposited by means of gas-phase deposition, which is a usual technique in semiconductor technology for providing a layer.

The breakdown voltage increasing means in the device according to the invention ensure that the pn-junction between the island-shaped region

and the insulating region is able to withstand the voltage which is offered at the contact pad during operation. As a result, the device according to the invention will still continue to function reliably, also in the case of any short-circuit in the insulating layer.

The invention will now be explained in more detail with reference to a drawing in which:

Fig. 1 is a cross-section of a first embodiment of the device according to the invention, and

Fig. 2 is a cross-section of a second embodiment of the device according to the invention.

The Figures are purely diagrammatic and not drawn to scale. In particular, some dimensions are shown on a strongly exaggerated scale for the sake of clarity. Semiconductor regions of the same conductivity type are hatched in the same direction as much as possible, and corresponding parts are given the same reference numerals.

The device of Fig. 1 comprises a semiconductor body with a p-type substrate of silicon and a superimposed n-type epitaxial layer 2 with an average phosphorus concentration of $6 \cdot 10^{14} \text{ cm}^{-3}$. The epitaxial layer 2 comprises a number of island-shaped regions 3 which are each surrounded by a p-type insulating region 4 with an average boron concentration of approximately $5 \cdot 10^{19} \text{ cm}^{-3}$ which extends from the surface to the substrate 1. The insulating region may be formed, for example, through a combination of diffusion from the surface and from a buried layer.

On the surface there is an approximately 2.5 μm thick silicon oxide layer of which approximately 0.1 μm was grown thermally on the surface, but the remaining portion was provided by gas-phase deposition (CVD). A contact pad 6 of aluminium with dimensions of approximately $100 \times 100 \mu\text{m}^2$ is provided on the oxide layer 5 in the location of an island-shaped region 3. The contact pad 6 is connected to a switching element situated elsewhere in the semiconductor body by means of an aluminium conductor track outside the plane of the drawing.

To protect the device, the entire assembly is coated with a protective top layer 7 of silicon nitride in which a window is provided at the area of the contact pad 6. A contact wire may be fastened on the contact pad 6 in the window in order to connect the device to a lead of a lead frame (not drawn). It is alternatively possible that only a small metal elevation is provided on the contact pad, a so-called bump, whereby the device can be mounted directly on a lead frame or a tape.

In all these cases, pressure is exerted on the contact pad 6, so that stresses are introduced into the subjacent insulating layer 5. As a result of these, cracks may arise which may cause a short-circuit between the contact pad 6 and the island-

shaped region 3. In that case the voltage offered at the contact pad is applied fully across the pn-junction 34 between the island-shaped region 3 and the surrounding insulating region 4. This problem arises especially when the insulating layer was provided by means of a deposition technique, as in the present case. In contrast to grown layers, deposited layers are usually comparatively resilient, so that the layer will quickly break if pressure is exerted on it locally.

To counteract undesirable consequences of such a short-circuit, the device according to the invention is provided with means for increasing the breakdown voltage of the pn-junction 34 between the island-shaped region 3 and the insulating region 4. In this example, the breakdown voltage increasing means comprise a lateral extension 40 of the insulating region 4 adjoining the surface with a comparatively low doping concentration of approximately $5 \cdot 10^{16} \text{ cm}^{-3}$. The extension 40 extends approximately $30 \mu\text{m}$ into the island-shaped region 3, maintaining a distance 1 of approximately $20 \mu\text{m}$ from the contact pad 6.

In practice, a pn-junction such as the pn-junction 34 surrounding the island-shaped region 3 and situated transverse to the surface is found to be most susceptible to breakdown near the surface. To increase the breakdown voltage of the pn-junction 34, therefore, it is especially necessary to reduce the electric field around the pn-junction 34. The extension 40 sees to this. As a result of this extension, the depletion region which surrounds the pn-junction 34 during operation is considerably wider near the surface, so that the electric field is weakened. Without such an extension the pn-junction 34 in this example would not be able to withstand voltages above 170 V; with the extension voltages up to 300 V can be accommodated without problems.

The device of Fig. 2 largely corresponds to that of Fig. 1, the difference being that in this second embodiment of the device according to the invention the breakdown voltage increasing means comprise not only a lateral extension 40 of the insulating region 4, but also a number of p-type zones 41 adjoining the surface. The p-type zones 41 lie in the island-shaped region 3, forming narrow rings therein which entirely surround the contact pad. The zones have a width b of approximately $6 \mu\text{m}$ and can be applied in the same process step as the extension 40.

The interspacing λ between the zones 41 and between the zones 41 and the extension 40 is approximately $6 \mu\text{m}$, sufficiently small to ensure that during operation the depletion regions around the surface zones 41 and around the pn-junction 34 mutually overlap. As a result, the depletion region around the pn-junction 34 is further widened at the

surface, so that the electric field strength in the depletion region drops still further. This results in a further increase in the breakdown voltage of the pn-junction 34. In the device shown here, the pn-junction 34 was found to resist voltages of more than 1400 V.

Although the invention was described with reference to only two embodiments, it will be obvious that the invention is by no means restricted to the embodiments given. Many more variations are possible for those skilled in the art within the scope of the invention. Thus, in the examples given, the conductivity types may all be simultaneously replaced by the opposite conductivity types. In addition, those skilled in the art, within the scope of their skills, are aware of alternative breakdown voltage increasing measures which may be taken in the device according to the invention. Thus, for example, the so-called RESURF principle may be used in suitable locations in the device for further increasing the breakdown voltage of the pn-junction.

Claims

1. A semiconductor device comprising a semiconductor body with an island-shaped region of a first conductivity type adjoining a surface of the semiconductor body and being surrounded by an insulating region of a second, opposite conductivity type with which the island-shaped region forms a pn-junction, the island-shaped region being covered by an insulating layer on which a contact pad is provided, characterized in that the device is provided with means for increasing the breakdown voltage of the pn-junction between the island-shaped region and the adjoining semiconductor region.
2. A semiconductor device as claimed in Claim 1, characterized in that the means comprise a lateral extension of the insulating region, which extension adjoins the surface, extends into the island-shaped region, and has a lower doping concentration than the remaining portion of the insulating region.
3. A semiconductor device as claimed in Claim 1 or 2, characterized in that the means comprise a number of zones of the second conductivity type adjoining the surface, which zones are provided in the island-shaped region and are entirely surrounded by the island-shaped region in the semiconductor body.

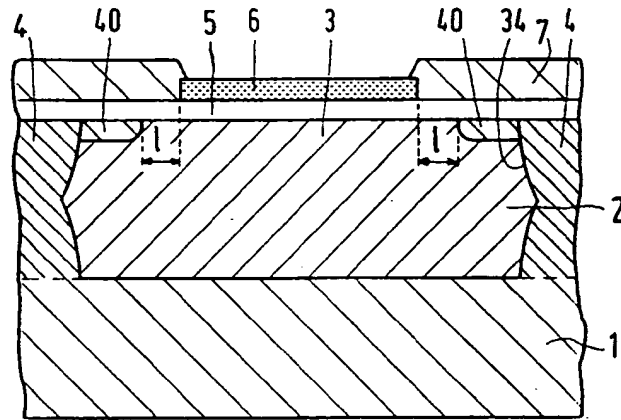


FIG.1

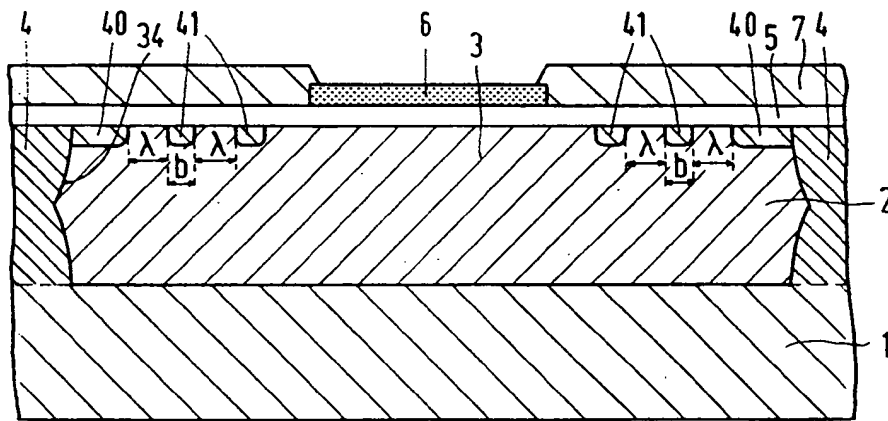


FIG.2

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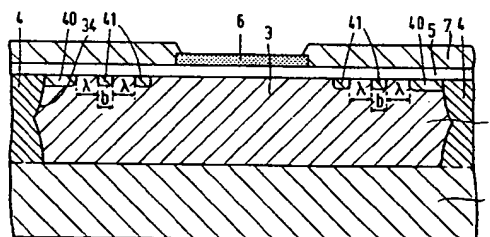
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**FIG.2****EP 0 521 558 A3**



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D,Y	US-A-3 812 521 (MOTOROLA INC) * abstract; figures *	1-3	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 106 (E-726)14 March 1989 & JP-A-63 278 244 (FUJITSU LTD) 15 November 1988 * abstract *	1-3	
A	EP-A-0 165 644 (PHILIPS) * abstract; figures *	3	
A	EP-A-0 262 723 (SGS MICROELECTRONICA) * column 5, line 5 - line 9; figure 1D *	1-3	
A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 130 (E-502)23 April 1987 & JP-A-61 274 343 (TOSHIBA CORP) 4 December 1986 * abstract *	1-3	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 04 MARCH 1993	Examiner SINEMUS M.
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
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A	EP-A-0 400 934 (GENERAL ELECTRIC COMPANY) * abstract; figures *	1-3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 04 MARCH 1993	Examiner SINEMUS M.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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